Beirut Air Pollution and Health Effects BAPHE Study

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Int r oduct ion

Multiple twentieth century air pollution disasters raised public health concerns since it became evident that extremely high levels of particulate-based smog can produce a large increase in the daily mortality rate. Since the London pollution episodes in 1952, air pollution has been associated with an increase in mortality and hospital admissions for diseases of the respiratory system [1,2]. Many studies have shown that high concentrations of air pollutants, specifically particulate matter (PM), have led to an increase in hospital admissions for diseases of the respiratory and cardiovascular systems [3-8]. Even low levels of air pollution are associated with negative health effects [9,10]. Although Lebanon is a highly polluted country, only in the last decade has it experienced an increase in environmental investigations on air quality. These studies have covered a variety of issues related directly or indirectly to air pollution, such as the contribution of the transportation sector in greenhouse gas emissions [11] and vehicle and emission sources in Beirut [12,13]. Some have even attempted to quantify the health effects of air pollution [14], but but with limited success.
The Beirut Air Pollution and Health Effects (BAPHE) study aimed to investigate the relationship between PM concentrations in the city of Beirut and daily emergency hospital admissions for diseases of the respiratory and cardiovascular systems, based on the findings of international and local studies and a validated methodology [15].

Materials and Methods

The data reported here is part of the BAPHE study phase I, an eco-epidemiological time-series project aiming to quantify the short-term health effects of air pollution in Beirut [15]. The relationship between daily levels of particulate matter PM10 and PM2.5 and emergency hospital admissions for respiratory and cardiovascular conditions was evaluated from January 2012 to December 2012. Potential confounders were taken into consideration. The Ethics Review Board (IRB) of each participating hospital have reviewed the BAPHE study protocol

(a) Study area
Beirut is located on the eastern coast of the Mediterranean Sea, covering an area of 20.8 km2,
with an estimated 378,485 individuals [16]. The city is characterized by two hills, separated by a thalweg. Each hill is approximately 100 m above sea level.

Both hills overlook the Mediterranean Sea from the north and west sides of the city. This complex and unusual topography with street canyons plays an important role in climate parameters, such as diversion of air masses and sunshine [17]. Therefore, the sea allows dissipation of pollutants by winds along the coast, but the land-facing sides of the hills are sheltered from the dominant wind. Beirut exhibits variations in temperature between the center and the suburbs, which implies a change in pollution levels. Therefore, if conditions are adequate, inversion occurs, and pollutants are trapped.

(b) Air pollution and weather data
In Beirut, air pollutant data were collected by the Air Quality Research Unit (AQRU) network. This network has stations in the city of Beirut and has been operating since 2004. The main pollutants that are measured are NO2, PM10, PM2.5, and O3. The first phase of BAPHE analysis was for a period of 12 months and considered PM10 and PM2.5 as pollution indicators. PM10 and PM2.5 were collected hourly, and daily averages were calculated from the closest monitoring site to the hospitals. Quality assurance procedures and instructions were implemented in each step of the measurement process. The mean daily relative humidity, temperature, wind direction, and speed data were also collected from the AQRU surveillance station. Seasonality was also controlled in the time series model.

(c) Hospital admissions data
Seven of the nine eligible hospitals in Beirut were included in BAPHE. Health data were extracted from emergency hospital admission registers of the seven hospitals by trained individuals. Data on age, sex, date of admission, first diagnosis, final discharge diagnosis, treatment in the emergency room (ER), and whether patients had been admitted or transferred to other hospitals were obtained on a daily basis for selected symptoms. Information on emergency hospital admissions for diseases of the respiratory (J00–J99) and cardiovascular (I00–I99) systems as per the Tenth Revision of the International Classification of Diseases (ICD10) was considered. Data from participating hospitals were reorganized to produce total daily hospital admissions in the diagnostic categories mentioned above.

(d) Data on potential confounders
The flu season (December to January) was controlled while estimating the relative risk in our model. Daily pollen count was not collected because of the non-availability of data.

(e) Data analysis
Descriptive analysis was performed to present the quantitative variables (hospital admissions, level of pollutants, and environmental factors) as mean and standard deviation according to quarters, flu season, and day of the week. The study of the association between hospital admissions for selected conditions (diseases of the respiratory and cardiovascular systems) and the level of pollutants at different lags, controlling for possible confounding factors, such as mean daily temperature, relative humidity, day of the week, and flu period was also performed.
Relative risks (RRs) are shown as a 10-unit increase in PM from the WHO reference.

Results

1. Characteristics of admissions
This first stage of the BAPHE study was conducted for 12 months (January 2012–December 2012). Approximately 80,000 patients visited the emergency department of six hospitals in Beirut during this study period. Among these, 11,534 were diagnosed with respiratory, circulatory, cerebrovascular, and allergic skin diseases. A total of 4016 patients were diagnosed with circulatory diseases and 6790 with respiratory symptoms. Table 1 shows the main characteristics of the patients considered in the BAPHE study. Approximately 70 % of patients whose data were collected belonged to the age group younger than 65 years. The daily number of emergency hospital admissions ranged from 3 to 46 admissions and from 2 to 24 admissions for respiratory and circulatory diseases, respectively (Table 2). The daily mean number of emergency hospital admissions (±standard deviation) was 19 ±7 for respiratory admissions and 11±4 for circulatory admissions.

Table 1: Characteristics of emergency hospital admissions patients for diseases of respiratory and circulatory systems.

Age group	Male	Female	Total	Proportion of age group %
Age 0-15	1368	907	2275	21.05
Age 16-64	3000	2243	5243	48.50
Age 65 et +	1638	1655	3293	30.45
Total	6006	4805	10811	100.00

Table 2 Descriptive statistics of daily pollutants concentrations (µg.m-3), meteorological variables and hospital admissions (diseases of the respiratory system (J00-J99) and system (I00-I99), 2012.

Statistic	PM10 (µg.m^{-3})	PM2.5 (µg.m^{-3})	T(˚C)	RH (%)	Number of admissions I00 to I99	Number of admissions J00 to J99
No. of observations	366.00	366.00	366.00	366.00	366.00	366.00
Minimum	15.96	4.24	7.21	33.50	2.00	3.00
Maximum	359.67	208.61	28.50	75.04	24.00	46.00
1st Quartile	32.78	18.61	15.17	45.72	8.00	14.00
Median	43.92	26.63	19.69	50.02	10.00	18.00
3rd Quartile	58.40	35.92	25.16	57.75	13.00	23.00
Mean	50.54	30.16	19.69	52.05	11.00	19.00
Standard deviation	32.12	19.17	5.62	8.53	4.00	7.00

From December to January and May to July, the daily number of admissions for respiratory disease was higher compared with that for the rest of the year (Figure 1). The high level of respiratory admissions in the first period can be explained by the flu season. But the second increase cannot be attributed to flu season because there is no flu period at this time of the year in Lebanon. Therefore a likely explanation for this increase can be attributed to air pollution and particles. Besides, the results of Farah et al. in 2014 (Farah et al. 2014a, b) confirm that PM2,5 and PM10 concentrations were higher in June and July 2012 compared with other periods of the year.

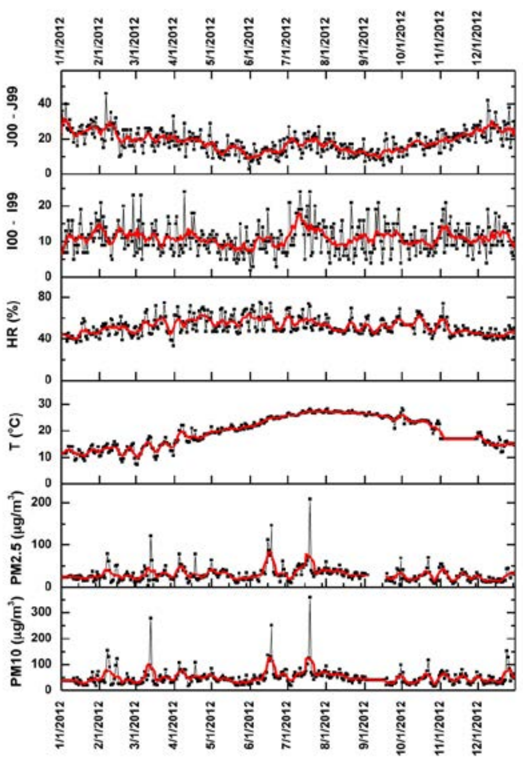

Figure 1 Time series plots of selected air pollutants, meteorological data and hospital admissions for respiratory diseases (J00-J99) and cardiovascular diseases (I00-I99). (red line represents the moving average over 7 days)

2. Characteristics of PM10 and PM2.5 and meteorological factors

Table 2 shows the descriptive statistics of PM10, PM2.5, and meteorological factors. PM10 and PM2.5 concentrations were measured on 366 days, from January to December 2012. The daily average concentrations of PM10 and PM2.5 were 50.5±32.12 and 30.16± 19.17 µg.m−3, respectively. During the study period, the mean daily temperature was 19.69 °C and humidity was 52.05 %, reflecting the typical Mediterranean climate.

3. Characteristics of the association

RR were 1.012 [95 % CI 1.004–1.02] per 10 µg.m−3 rise in daily mean pollutant concentration for PM10 and 1.016 [95 % CI 1.000–1.032] for PM2.5 on the same day. A nearly significant association was also observed after 6 days (at lag 6). Significant associations at lags 6 and 7 were also found between PM10 and PM2.5 and respiratory admissions in the adults group. There was a delayed lag effect obtained for this category. Cumulative exposure was addressed during data analysis, and no significant association was found before lag 6 and 7. RRs were 0.997 [95 % CI 0.986–1.008] and 1.008 [95 % CI 1.000–1.016] at lags 2 and 5, respectively.

In children, total respiratory admissions were associated with PM2.5 and PM10 concentrations. The RRs (95 % CIs) were 1.013 (0.985–1.042) and 1.014 (1.000–1.029) for PM2.5 and PM10 within the same day, respectively. This relation was also significant for PM2.5. For diseases of the respiratory system in the elderly group, RRs (95%CIs) were 1.036 (1.011–1.06) for PM2.5 and 1.019 (1.006–1.032) for PM10. This result is consistent with international studies (Schwartz 1995; Martins et al. 2002; Chen et al. 2004), which showed that elderly people (aged >65 years) are more sensitive to pollutants than young people.

Moreover, a nearly significant association was found between PM10 and PM2.5 and total circulatory admissions for the adults and elderly groups in the same day. For every increase in 10 µg.m−3 in daily mean levels of PM2.5 and PM10, the RRs and 95%CIs were 1.02 (0.993–1.037) and 1.0 (0.998–1.021) in the adults group and 1.02 (0.993–1.054) and 1.01 (0.989–1.022) in the elderly group.

Discussion

The BAPHE study has shown in 2015, for the first time in Lebanon, the short-term The BAPHE study has shown in 2015, for the first time in Lebanon, the short-term

		Respiratory emergency admissions			Circulatory emergency admissions		
Age	**Pollutant**	**Lag**	**RR**	**95% CI**	**Lag**	**RR**	**95% CI**
Less than 16 years	$PM_{2.5}$	0	**1.013**	(0.985;1.042)	**0**	**-**	-
	PM_{10}	0	**1.014**	(1.000;1.029)	**0**	**-**	-
16-64 years	$PM_{2.5}$	6	**1.010**	(1.001;1.019)	**0**	**1.02**	(0.993;1.037)
	$PM_{2.5}$	7	**1.010**	(1.001;1.019)			
Over 64 years	PM_{10}	6	**1.006**	(1.001;1.011)	**0**	**1.01**	(0.998;1.021)
Total	PM_{10}	7	**1.006**	(1.001;1.011)			
	$PM_{2.5}$	0	**1.036**	(1.011;1.06)	**0**	**1.02**	(0.993;1.054)
	PM_{10}	0	**1.019**	(1.006;1.032)	**0**	**1.01**	(0.989;1.022)
	$PM_{2.5}$	0	**1.016**	(1.000;1.032)	**0**	**1.02**	(0.999;1.036)
	$PM_{2.5}$	6	**1.004**	(0.998;1.011)			
	PM_{10}	0	**1.012**	(1.004;1.02)	**0**	**1.01**	(0.998;1.018)
	PM_{10}	6	**1.003**	(0.999;1.006)			

We took into account various factors when planning our study. First, potential participating hospitals were considered based on a selection criterion and on their ability to provide data. Our data collection and analysis methodology were centralized in one location and verified by three people, thus, providing homogeneity. Health and environmental data and information on confounders were collected following specification and predefined forms to ensure consistency.

Second, our model considered the main confounders that could affect the study. Meteorological factors and periodic fluctuations in hospital admissions, such as flu season, were controlled. However, data were not available for pollen count, as reported in several international studies [18-20], and this could represent a residual source of confounding due to asthma.

The first phase of the study was short compared with other multicenter studies, but the mean daily admissions for respiratory and cardiovascular illnesses were relatively large for the study area.

Our findings are similar to those of in European countries and US cities [4-6]. Our estimated short-term size effect of PM10 for an increase of 10 µg.m−3 was 1.2 % in respiratory admissions, which falls within the range (0.8–3.4%) reported by Dockery and co-investigators in 1993 [20]. Our results are consistent with findings reported by Wong and colleagues in 1999 and Schwartz in 1995 [19,22] on the association between air pollution and hospital admissions for respiratory diseases, especially for the elderly group. Anderson and co-investigators showed in 1995 a nonsignificant increase in respiratory diseases for all age groups[21]. However, their analysis of the 65+ age group showed an important relative risk (RR=1.19) for respiratory diseases, which agrees with our results. Comparison with research conducted in 1999 in Birmingham [18] confirmed our results on the significant association between PM10 and respiratory admissions.

A significant delay (6 to 7 days) was observed between the increase in air pollution level and emergency hospital admission in the adults group, which is consistent with several international studies [23]. Moreover, we attempted to understand this delay and found that socioeconomic and cultural factors affect the time between the first symptoms of disease and seeking medical care in the ER. Lebanese people have relatively easy access to physicians in private clinics in the acute setting and can therefore be overlooked when analyzing only ER data. When their symptoms are severe, they are referred to hospitals for admission. Therefore, the entire process of hospital admissions is delayed, and the proportion of people arriving to the ER could represent severe cases. Additionally, economic situations can force patients to postpone medical care.

The prospective data compilation in the BAPHE study should be considered an advantage of the study. Data were extracted especially for the project and not for other reasons. Finally, similar to all eco-epidemiological studies, the BAPHE has an important limitation, which is the inability to estimate exposure precisely. Therefore, cause effect relations were unable to be addressed.

Conclusion

Worldwide, many studies have shown adverse effects of air pollution on health. The BAPHE study was the first to attempt to study this relation in Lebanon. The reason for conducting such studies is to redesign public health policies and reevaluate air quality standards. We provided new evidence on adverse health effects of particles in Beirut. We observed a significant effect of PM on emergency hospital admissions for diseases of the respiratory and cardiovascular systems. Our results have a similar range to those already published worldwide, suggesting that serious interventions are required to reexamine Lebanese public health objectives, air quality standards, and their enforcement.

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